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DETERMINATION OF EXCAVATION DISTURBANCE IN ROOM 209 UNDERGROUND RESEARCH LABORATORY

Report No 88-65-K

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ABSTRACT

The borehole dilatometer was used in room 209 at the Underground Research Laboratory (URL) in Manitoba to assess excavation disturbance within the rock mass. Deformation moduli were measured at various locations with depth from the tunnel wall and profiled. Results suggest that excavation disturbance was limited to less than a meter and a half in all holes except vertically down where disturbance of approximately three meters was determined.

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DETERMINATION OF EXCAVATION DISTURBANCE IN ROOM 209-UNDERGROUND RESEARCH LABORATORY

1.0 INTRODUCTION

The borehole dilatometer was used to assess excavation disturbance in the rock mass surrounding room 209 in the Underground Research Laboratory (URL) as part of the 240 level characterization program. The purpose of the work was to continue the development and testing of methods for the assessment of excavation disturbance in order to establish a methodology which would be available at the time when Operating Phase Experimental Programs commenced. This work was undertaken as part of Ontario Hydro's Technical Assistance Program (TAP) to AECL.

2.0 TESTING LOCATION

Testing was undertaken in room 209 at the 240 level in the Underground Research Laboratory (URL). This room is oriented in a direction perpendicular to the maximum principal in situ stress direction. Four 10 m long EWG holes were drilled at right angles to the tunnel axis at chainage 28 m in room 209 (Figure 1). These holes, which were oriented vertically up, vertically down and horizontally into each wall, permitted dilatometer testing in the tangential stress direction.

The EWG stress meter holes were oriented parallel to the axis of room 209. These holes were extended 1.5 m to allow dilatometer testing in the radial stress direction. These test holes are shown in Figure 1.

3.0 EQUIPMENT AND TESTING PROCEDURE

The testing program was undertaken with the aid of a computerized borehole dilatometer system. Details concerning this equipment are provided elsewhere (Koopmans and Hughes, 1984) and will, therefore, not be reported here.

Prior to testing, the dilatometer was calibrated in both an aluminum and steel thick-walled cylinder. Each cylinder had an inner diameter of 3.81 cm, an

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outer diameter of 11.44 cm and an overall length of 30.48 cm. Five cycles were run for each calibration with the last four recorded. The first cycle was used to seat the dilatometer in the cylinder. After calibration, the dilatometer was placed in the borehole using placement rods. Once again five cycles were used with the last four recorded. Due to the very small volume changes which occur within the dilatometer, especially in high modulus rocks, it was determined that more accuracy could be obtained by averaging the slopes of the four curves. Pressures in the order of 2 MPa were used to seat the dilatometer while pressures of approximately 32 MPa were used at the top of each cycle. Borehole testing progressed by moving the dilatometer from the collar to the bottom of the hole. Upon completion of testing, the borehole calibrations were taken once again to verify the original calibrations. With the aid of a computer, both pressure and volume were recorded every second and stored on disc.

In the 10 m long holes, tests were conducted at 0.25 m intervals from 0 to 5.0 m and at 0.5 m intervals from 5.0 to 10.0 m. In the 1.5 m section at the bottom of the stress meter holes, three tests were conducted at approximately 0.25 m intervals.

4.0 DATA REDUCTION

Both the secant and tangent moduli were calculated for all test locations. The tangent modulus was determined from the straight line portion of the curve, while the secant value was determined from the slope between the maximum applied pressure and the seating pressure (2 MPa). The slope values for all four runs were averaged for each test. A computer program was used to determine the deformation modulus. The complete derivations of equations required for the calculation of deformation modulus of rock is provided by Hustrulid and Hustrulid (1975). The basic equations are presented by Koopmans and Hughes (1984). The only difference in these equations is that our calculations are expressed as pressure-volume instead of pressure/turn.

The results of all test locations in the four 10 m long holes were plotted to show the profile of deformation moduli with depth for each borehole (Figures 2 to 5). The tests undertaken in the bottom of the stress meter holes were averaged and are not profiled since they were all conducted at the same depth from the tunnel face (ie, boreholes are parallel to tunnel axis).

5.0 DISCUSSION OF RESULTS

The calculated secant and tangent deformation moduli for each 10 m long borehole are shown in Table 1 and the borehole profiles are shown in section view in Figures 6 and 7.

Borehole 209-029-DIL1 (horizontal south wall) shows that the extent of the excavation disturbance is about 0.5 m (Figure 2). The average moduli calculated were 39.9 GPa for the secant and 63.0 GPa for the tangent. The most notable variance in the results occurs between 6.5 and 8.5 m, where extremely high moduli were obtained. This zone appears to be so highly

stressed that the dilatometer tests performed are not valid. This occurs when the rock mass has a higher stiffness than the testing equipment and results in equipment expansion rather than rock mass expansion.

Borehole 209-029-DIL2 (vertical down) shows that the extent of the excavation disturbance is in the order of 3 m in the rock mass (Figure 3). This would equate to approximately 3.5 m from the top of the fill in the bottom of the tunnel. The average moduli calculated were 41.5 GPa for the secant and 53.7 GPa for the tangent. A highly stressed zone was noted at a depth from 7.5 to 9.0 m. Moduli obtained in this area were not as high as those found in borehole 209-029-DIL1. Any correlation between the two zones is not known. The greater depth of excavation disturbance experienced in this borehole is most likely due to the more heavily charged lifter holes which were used in the floor area during excavation.

Borehole 209-029-DIL3 (horizontal north wall) shows that the extent of excavation disturbance is approximately one and a quarter meters (Figure 4). The average moduli calculated were 35.1 GPa for the secant and 49.4 GPa for the tangent. The results obtained in this borehole appear to be fairly consistent with depth with no unusual variances. It should be pointed out, however, that the average moduli obtained in this hole are lower than the average values calculated for borehole 209-029-DIL1 (horizontal south wall).

Borehole 209-029-DIL4 (vertical up) shows excavation disturbance to a depth of about one metre (Figure 5). Average moduli of 41.2 GPa for the secant and 55.5 GPa for the tangent were calculated. High moduli were found at the collar of the borehole. This would appear to result from the existence of high compressive stresses in the crown of the tunnel. These values drop off and level out at approximately one metre. At a depth between 6.5 m and 9.5 m, a zone of lower moduli was found. Core logs indicated the existence of core discing in this area (AECL, 1987). The lower moduli obtained suggest the possibility that fractures exist in the rock mass and only simulate core discing after the core has been removed from the borehole.

The deformation moduli obtained in the stress meter holes paralleling the tunnel axis are shown in Table 2. For comparative purposes, moduli at similar depths from the perpendicular dilatometer boreholes are shown in this table as well. It should be emphasized that accurate comparisons between the two directions is not possible since the exact testing locations are not known. This could make a significant difference in some instances where an unusually high moduli is obtained between two lower ones. This situation occurs in borehole 209-029-DIL2 for example, where within a depth of 0.5 m, the modulus increases from 42.0 GPa to 64.0 GPa and back down to 42.7 GPa (Figure 3). Needless to say, if the parallel borehole was located 0.5 m either way, the parallel modulus would be almost exactly the same as the perpendicular value. However, since the assumed depth of the borehole is 1.5 m, the modulus in the perpendicular direction is about 20 GPa higher.

Keeping this in mind, we can generalize and say that the tangent moduli in both directions are reasonably similar, with only minor variations noted. On the contrary, the secant moduli in the parallel direction are significantly lower than those obtained in the perpendicular direction. The reason for this is probably due to inward stress relaxation associated with the opening of fractures oriented in a direction parallel to the tunnel axis. Subsequent to the closing of these fractures, typical tangent moduli are obtained.

The lowest secant and tangent moduli in the stress meter holes were obtained in the floor, thus further suggesting that the more heavily charged lifter holes were responsible for this disturbance. Once more, lower moduli values were obtained in the stress meter holes in the north wall as compared to those in the south wall. This may indicate that the rock mass on the south side is higher stressed and less fractured.

6.0 SUMMARY

Based on the excavation disturbance project carried out with the borehole dilatometer system in room 209, the following observations were noted:

1. Excavation disturbance was less than 1.5 m in all boreholes except for 209-029-DIL2 in the floor, which showed disturbance to a depth of about three meters.

2. Zones of highly stressed rock were detected in boreholes 209-029-DIL1 and 209-029-DIL2.

3. Lower moduli, possibly due to tension cracks noted as discing in core logs, were obtained in borehole 209-029-DIL4.

4. High moduli which were noted at shallow depths in the roof, suggest the presence of high compressive stresses.

5. Average deformation moduli in the north wall were lower than those in the south wall.

6. Tangent moduli parallel and perpendicular to the tunnel axis were similar in magnitude.

7. Secant moduli parallel to the tunnel axis were substantially lower than those obtained at similar depths perpendicular to the tunnel axis.

7.0 CONCLUSIONS

Borehole dilatometer testing was undertaken in room 209 at the Underground Research Laboratory to assess excavation disturbance within the rock mass. Test results indicate that excavation disturbance was less than 1.5 m in all holes except vertically down, which revealed disturbance to a depth of approximately 3 m. This suggests that with the exception of the floor area, the blasting program carried out in this area of the tunnel, was very effective in minimizing rock wall disturbance.

ACKNOWLEDGMENTS

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TABLE 1

DEFORMATION MODULUS WITH DEPTH FOR 10 METRE BOREHOLES

Test Depth (m)	209-029-DIL1 Sec (GPa)	209-029-DIL1 Tan (GPa)	209-029-DIL2 Sec (GPa)	209-029-DIL2 Tan (GPa)	209-029-DIL3 Sec (GPa)	209-029-DIL3 Tan (GPa)	209-029-DIL4 Sec (GPa)	209-029-DIL4 Tan (GPa)
0.2	34.8	46.6	--	--	--	--	--	--
0.25	--	--	--	--	28.5	43.6	55.9	76.3
0.5	40.3	63.3	--	--	27.9	44.8	49.3	58.4
0.75	37.7	62.5	--	--	31.1	41.4	45.7	57.8
1.0	39.3	63.3	--	--	28.7	43.6	42.1	54.1
1.25	40.3	61.0	33.3	42.0	32.7	51.8	43.3	53.0
1.5	37.4	57.5	38.6	64.0	35.2	55.2	40.7	48.9
1.75	38.0	65.7	32.8	42.7	30.2	46.5	47.9	58.4
2.0	40.0	73.2	31.4	37.6	34.4	45.2	46.1	55.9
2.25	35.4	57.4	33.1	46.4	32.0	34.0	37.1	83.3
2.5	41.4	63.3	38.3	48.7	34.1	54.6	50.3	41.8
2.75	42.5	71.2	38.6	50.1	38.1	57.1	39.1	49.8
3.0	41.0	67.5	40.5	49.6	35.5	56.4	44.9	57.1
3.25	40.7	64.1	36.2	43.9	39.0	56.4	41.1	53.0
3.5	36.8	49.0	40.2	50.1	38.1	51.8	39.7	57.1
3.75	44.1	68.5	40.2	49.1	37.8	49.3	43.7	55.9
4.0	47.1	71.2	51.7	75.0	38.7	51.3	45.7	57.1
4.25	37.4	59.6	49.1	67.3	37.8	49.3	40.0	50.3
4.5	35.1	54.4	40.5	47.7	34.9	49.3	37.5	53.5
4.75	44.1	62.5	56.3	77.1	32.4	41.0	35.2	45.3
5.0	37.7	66.6	44.3	50.1	38.4	50.8	40.0	50.3
5.5	47.6	76.4	48.7	58.9	37.8	50.8	43.3	57.8
6.0	44.9	64.9	43.5	49.1	31.8	39.7	41.1	60.0
6.5	42.5	58.9	39.5	51.7	36.3	46.1	41.1	65.8
7.0	31.0	263.6(?)	46.8	60.3	37.8	53.5	33.7	51.4
7.5	99.2(?)	362.9(?)	48.2	67.3	37.2	51.8	30.7	48.9
8.0	126.9(?)	305.5(?)	70.9	88.6	39.7	54.0	27.3	50.3
8.5	48.0	94.0(?)	58.2	90.0	38.1	59.0	28.7	50.3
9.0	56.9	103.0(?)	56.3	94.7	33.9	51.8	27.8	52.4
9.5	--	--	48.2	72.9	36.3	49.3	36.1	54.1
9.84	--	--	--	--	39.3	48.3	--	--
10.0	--	--	51.7	87.1	--	--	--	--

Note: The question mark (?) in this table refers to questionable moduli, which were obtained in highly stressed zones.

TABLE 2

COMPARISON OF MODULI PARALLEL AND PERPENDICULAR TO THE TUNNEL AXIS

Location of Borehole	Direction to Tunnel Axis	Depth (m) of Test	Secant Modulus (GPa)	Tangent Modulus (GPa)
South Wall	Parallel	1.0	29.5	67.1
South Wall	Perpendicular	1.0	39.3	63.3
South Wall	Parallel	2.0	31.9	69.7
South Wall	Perpendicular	2.0	40.6	73.2
Floor	Parallel	1.0	21.7	51.7
Floor	Perpendicular	1.0	33.3	42.0
Floor	Parallel	2.0	22.3	45.8
Floor	Perpendicular	2.0	38.6	64.0
North Wall	Parallel	1.5	28.2	59.7
North Wall	Perpendicular	2.5	35.2	55.2
North Wall	Parallel	1.5	28.0	65.6
North Wall	Perpendicular	2.5	34.1	54.6
Roof	Parallel	1.0	24.7	62.5
Roof	Perpendicular	1.0	42.1	54.1
Roof	Parallel	2.0	26.9	53.7
Roof	Perpendicular	2.0	46.1	55.9

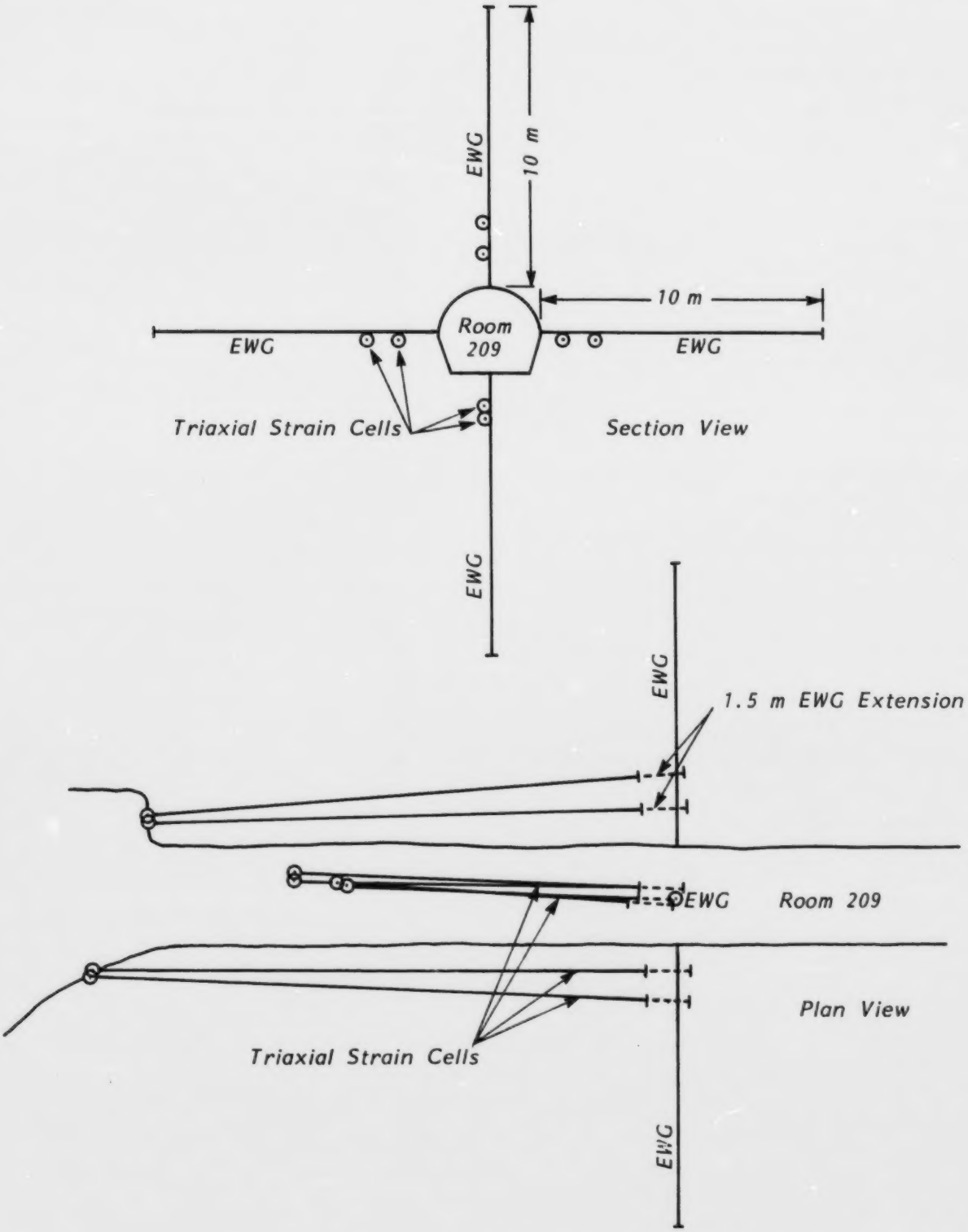

FIGURE 1
LAYOUT OF EXCAVATION DAMAGE ASSESSMENT HOLES IN ROOM 209
(AFTER LANG, 1987)

FIGURE 2 - URL MODULUS TESTING

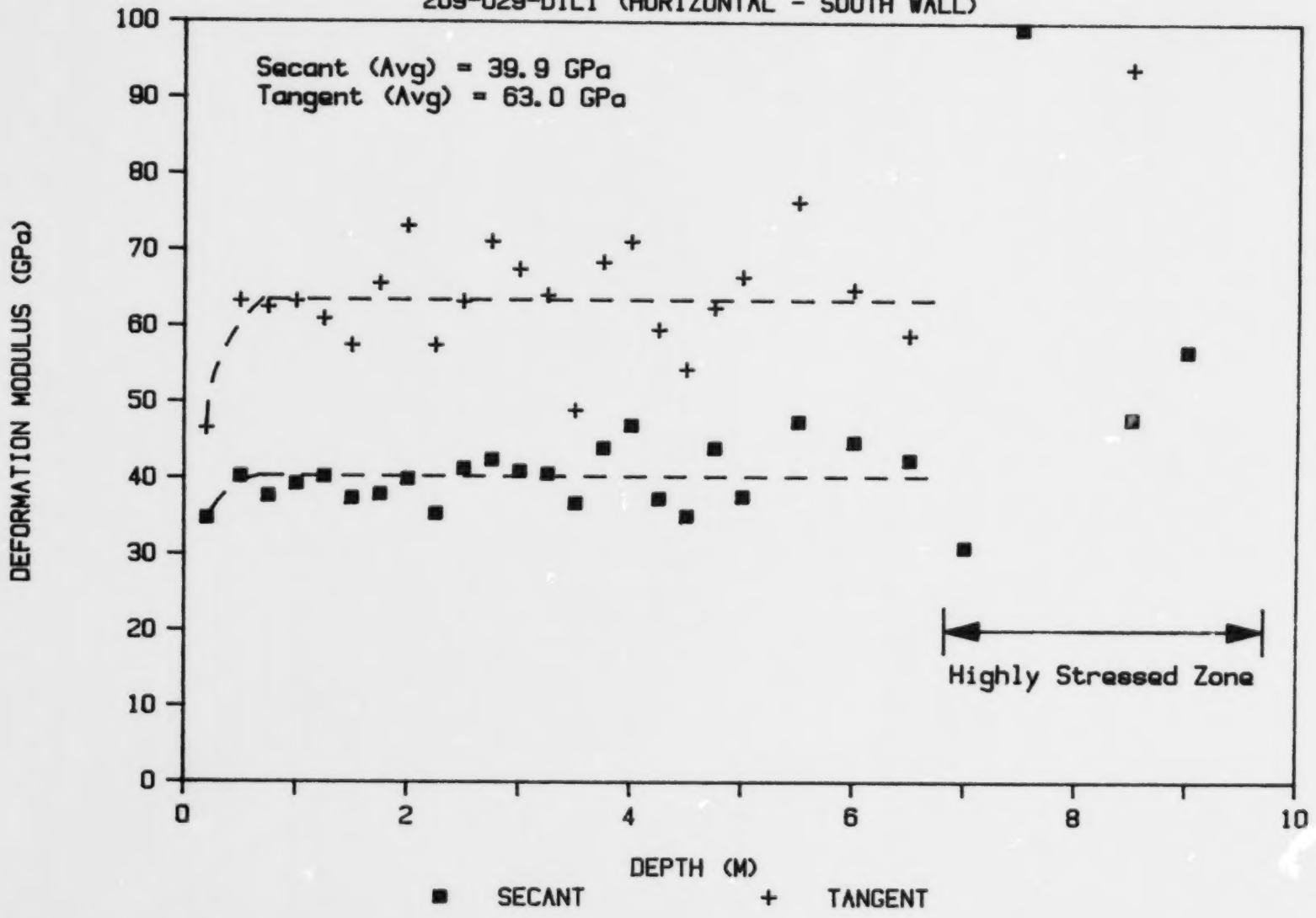

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FIGURE 3 - URL MODULUS TESTING

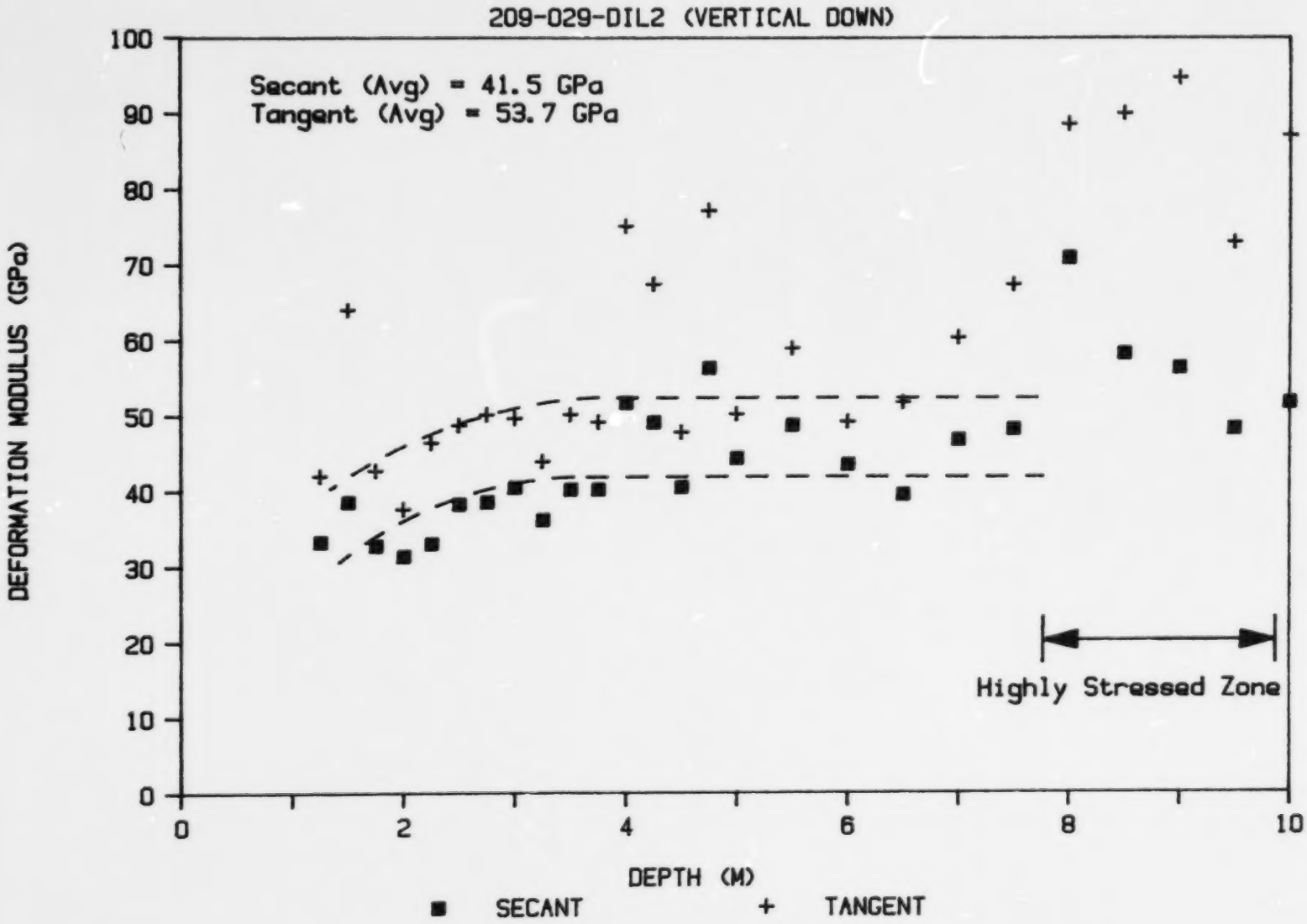

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FIGURE 4 - URL MODULUS TESTING

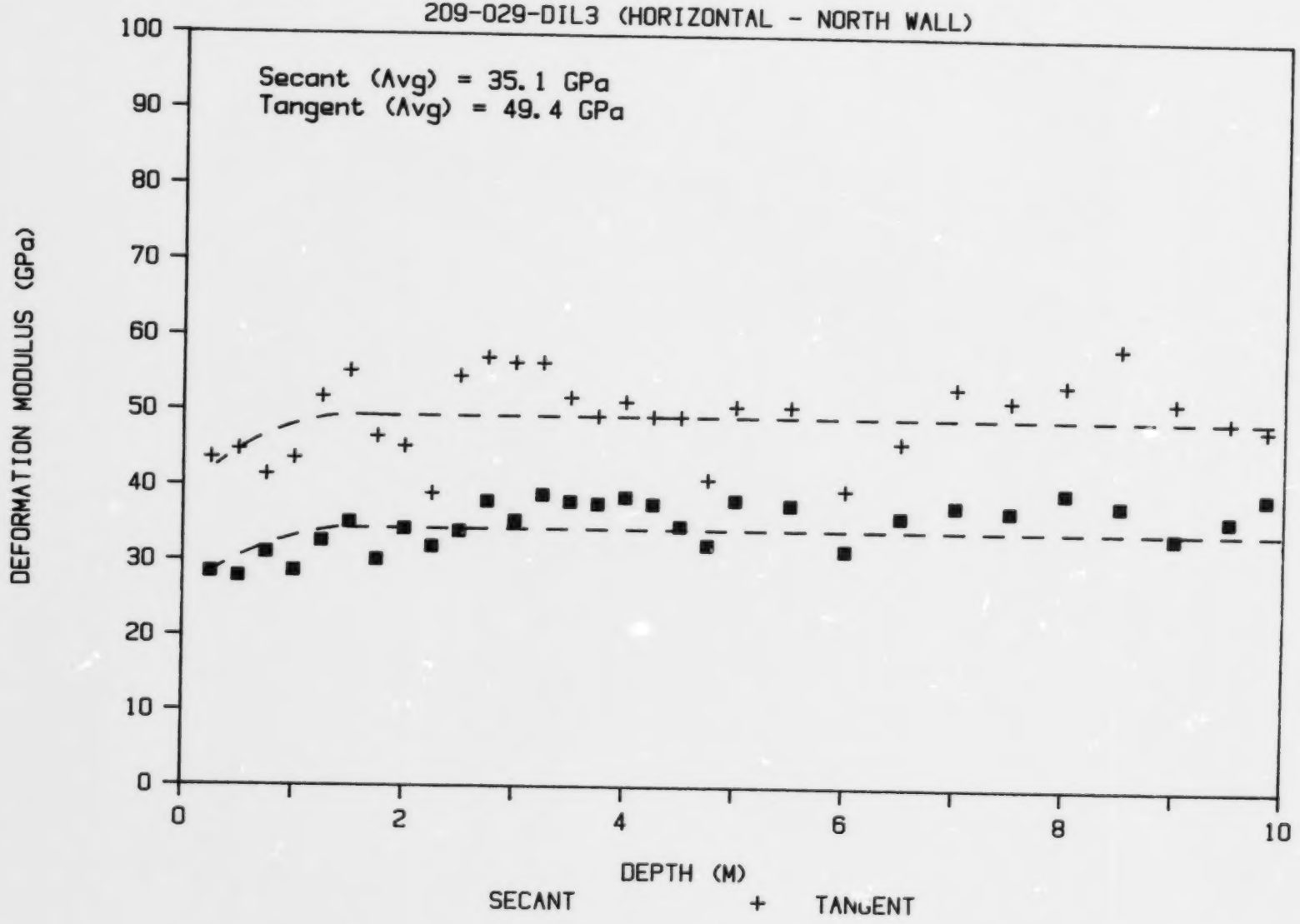
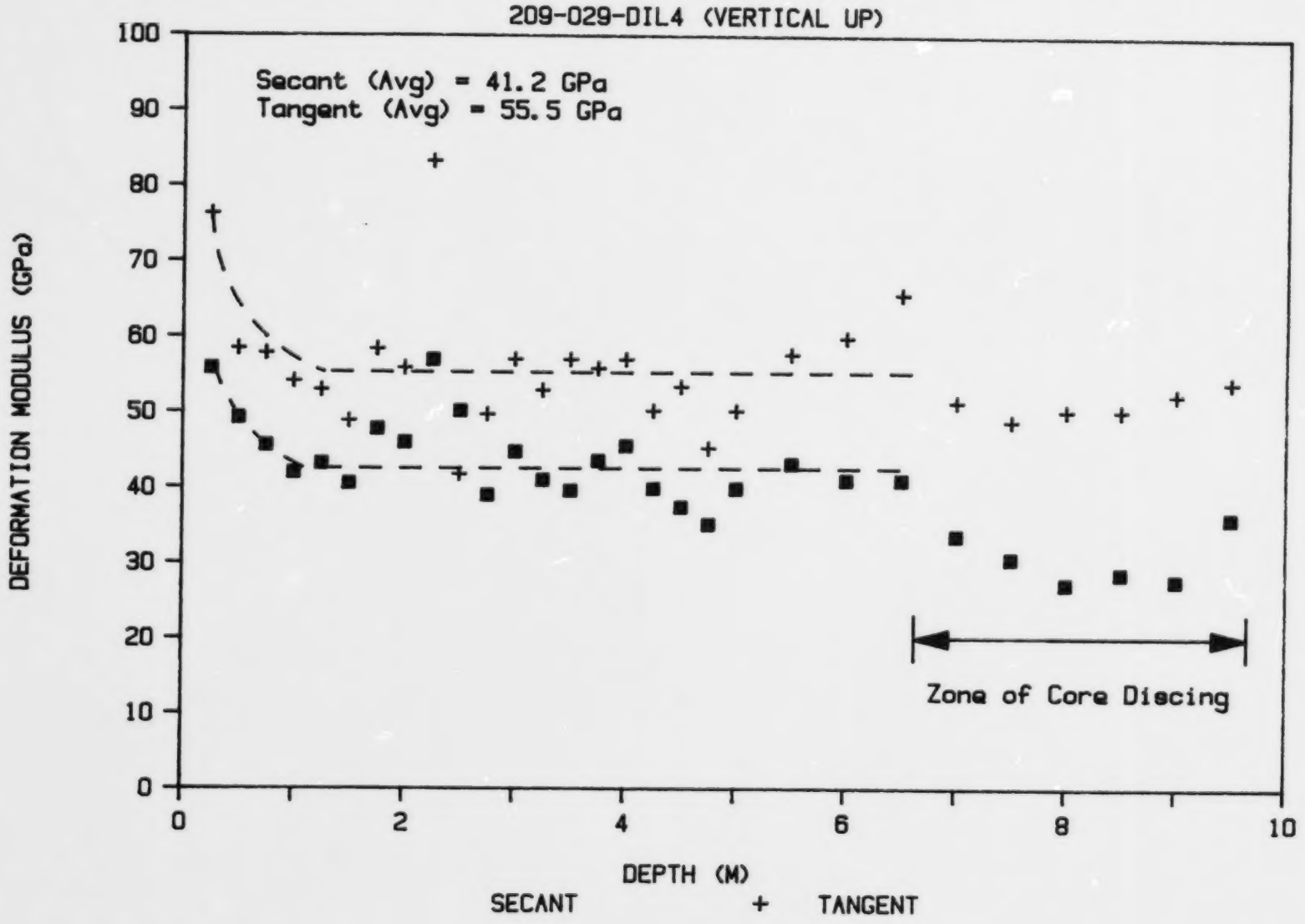


FIGURE 5 - URL MODULUS TESTING



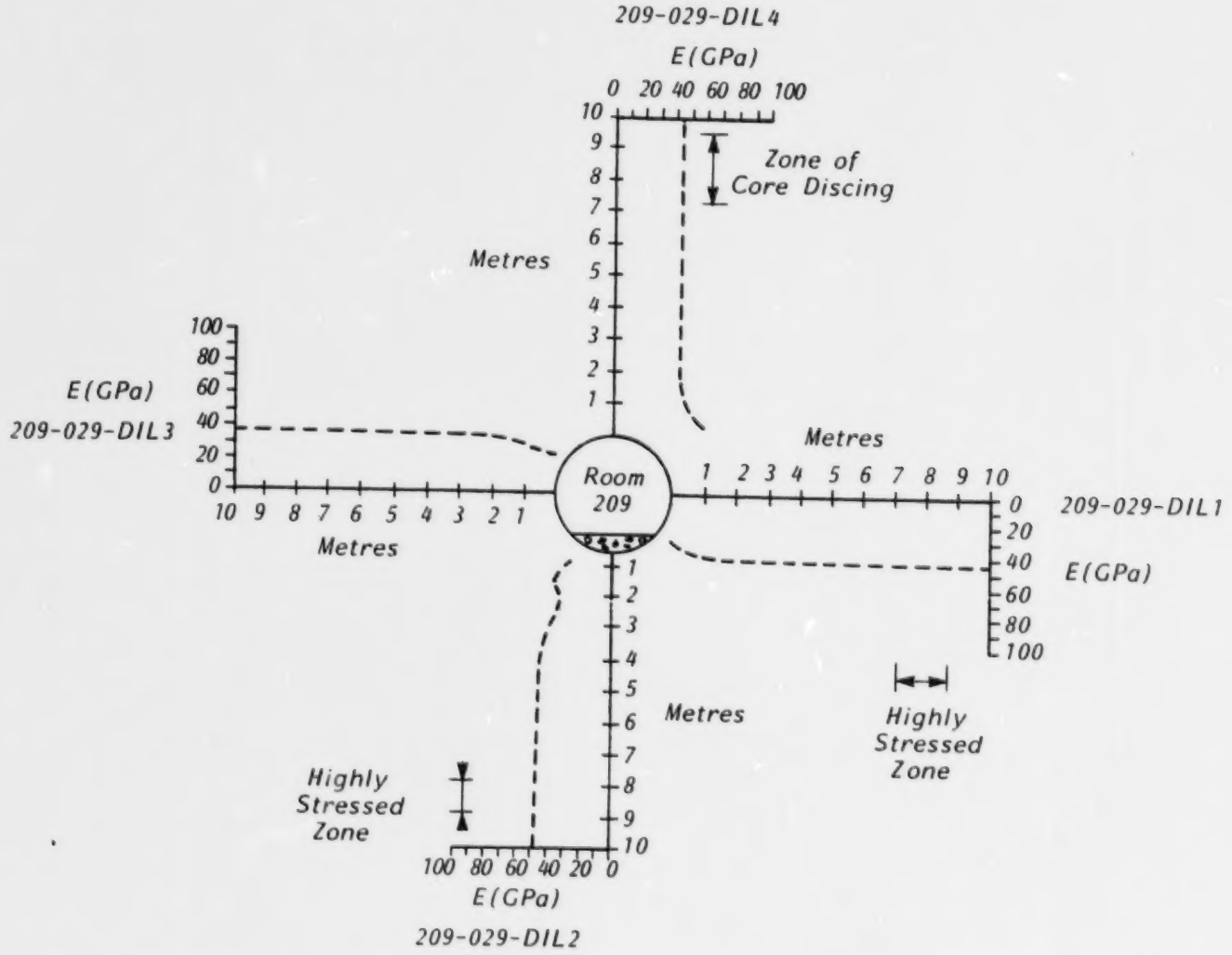


FIGURE 6

CROSS-SECTION OF ROOM 209 SHOWING SECANT MODULUS TREND WITH DEPTH FROM TUNNEL WALL

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176573-RD

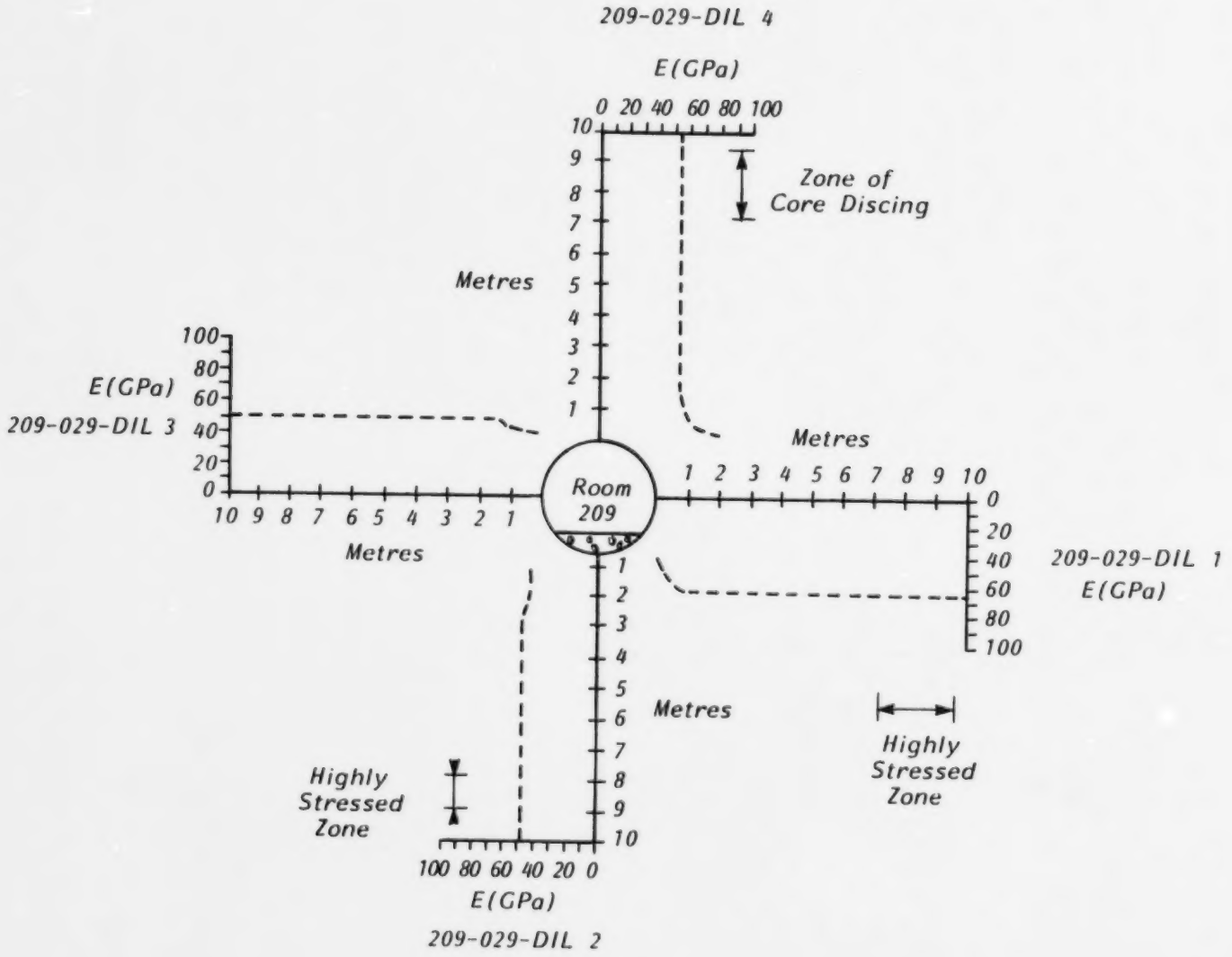

FIGURE 7

CROSS-SECTION OF ROOM 209 SHOWING TANGENT MODULUS TREND WITH DEPTH FROM TUNNEL WALL

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